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Date	:	30 APRIL 2008

COMPARING THE REMOVAL PERFORMANCE OF CO_2 GAS USING ADSORPTION ABSORPTION TECHNIQUES

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A Final Year Project Report submitted in partial fulfillment
of the requirements for the award of the degree of
Bachelor of Chemical Engineering (Gas Technology)

Faculty of Chemical Engineering & Natural Resources
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APRIL 2008

I declare that this thesis entitled "Comparing the Removal Performance of CO_2 Gas Using Adsorption Absorption Techniques" is the result of my own research except as cited in the reference. The thesis has not been accepted for any degree and is not concurrently submitted in any candidature of any other degree.

Signature	:	……
Name	:	NURULHAIDA BINTI LUHID
Date	:	30 APRIL 2008

To my family

Thank you for the support, encouragement and motivation that have been given

To all my friends

Thank you for the support and assistance that have been given

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ABSTRACT

Over the past century, the Earth has increased in temperature by about 5 °C and this is because of an increase in concentration of the main greenhouse gases; carbon dioxide. Therefore, a modification of gas phase of adsorption-absorption process was used. In the recent research, this technique was established by using a single adsorbent. To compare the effect of changing the gas removal techniques and to study the performance on the CO_2 gas removal from different adsorbent, Gas Absorption Adsorption Unit was used with granular activated carbon and zeolites as the adsorbents. For this purpose, purified CO_2 was used. This study was conducted using various gas flow rate (100, 75 and 50 m^3/hr) and water flow rate (250 and 200 L/hr). The experiment had been run twice at different condition; with present and absent of zeolites. At the end of the study, it was observed that increasing of gas flow rate reduce the composition of CO_2 dissolved in the water. On the other hand, increasing the water flow rate will increase the composition of CO_2 dissolved in the water solution. Beside that, higher gas flow rate increases the efficiency of the process. Increasing of water flow rate will increase the CO_2 composition dissolved even greater rather than increasing gas flow rate. The CO_2 composition dissolved in water is decrease with the present of zeolites. This shows that by having zeolites, it helps to decrease the rate of absorption of $C0_2$.The process will be more efficient if the CO_2 composition in the receiving vessel is high.

ABSTRAK

Sejak beberapa abad yang lalu, suhu Bumi telah meningkat sebanyak 5°C disebabkan oleh kandungan Gas Rumah Hijau yang tinggi; karbon dioksida. Untuk itu, pembaharuan dalam proses penyerapan-penjeraban gas dilakukan. Jika dibandingkan dengan kajian-kajian yang lalu, teknik menggunakan hanya satu jenis penyerap banyak dijalankan. Bagi membandingkan kesan perubahan teknik gas dan mempelajari perbezaan pencapaian gas pada penyerap yang berbeza, '*Gas Absorption Adsorption Unit*' telah digunakan bersama-sama dengan karbon aktif granul dan zeolite sebagai penyerap. Untuk itu, gas karbon dioksida tulen telah digunakan. Kajian telah dijalankan menggunakan variasi kadar alir gas (100, 75 and 50 m^3/j) and kadar alir air (250 and 200 L/j). Ujikaji telah dijalankan sebanyak dua kali pada keadaaan yang berbeza; dengan kehadiran dan tanpa zeolite. Pada akhir kajian, didapati bahawa peningkatan kadar alir gas mengurangkan komposisi gas karbon dioksida yang larut dalam air. Dalam erti kata yang lain, peningkatan kadar alir air menyebabkan peningkatan komposisi karbon dioksida yang larut dalam air. Selain itu, kadar alir gas yang tinggi menyebabkan keberkesanan proses meningkat. Apabila kadar alir air meningkat, komposisi karbon dioksida yang larut turut meningkat malah lebih besar dari peningkatan kadar alir gas. Komposisi karbon dioksida larut dalam air menurun dengan kehadiran zeolite. Ini menunjukkan dengan adanya zeolite, membantu kepada penurunan kadar penjeraban karbon dioksida. Kajian ini akan lebih efisyen sekiranya komposisi karbon dioksida pada vesel permulaan berada pada kedudukan yang tinggi.

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P	-	Pressure
P/P_o	-	Partial pressure
W	-	Width
V3	-	Valve
B1	-	Feed vessel
K1	-	Packed column
P1	-	Pump

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The 20th century has seen rapid increase of population and explosive growth in energy consumption. As more countries becoming industrialized, it is expected that more energy will be consumed in 21st century. EIA predicts 57 percent increase of energy demand from 2004 to 2030 (EIA, 2007). Table 1.1 shows the comparisons of energy use, population and per capita consumption in 1900 and 2001 (Song C, 2006). In current stage over 85 percent of world energy demand is supplied by fossil fuels. Fossil-fueled power plants are responsible for roughly 40 percent of total CO_2 emissions, coal-fired plants being the main contributor (Carapellucci and Milazzo, 2003).

Environmental issues due to emissions of pollutants from combustion of fossil fuels have become global problems, including air toxics and greenhouse gases (GHG). The CO_2 emission from human activity was on the order of 7 Gt/a in the late 1990's (Yamasaki, 2003). This includes the combustion of fossil fuels in all major industries and other factors such as deforestation and desertification.

Table 1.1: World energy use, population and per capita in 1990 and 2001 (Song C, 2006)

Energy Source	1900 Use		2001 Use	
	MTOE[a]	% or Unit	MTOE[a]	% or Unit
Coal	501	55	2395	24
Petroleum	18	2	3913	39
Natural Gas	9	1	2328	23
Nuclear	0	0	662	6
Renewable[b]	383	42	750	8
Total	911	100%	1004.8	100%
Population	1762	Million	6153	Million
Per capita E use	0.571	TOE[a]	1633	TOE
Global CO_2 emission	534	MMTCE[a]	6607	MMTCE
Per capita CO_2 emission	0.30	MTCE	1.07	MTCE
Atmospheric CO_2	295	ppmv[a]	371	ppmv
Life expectancy	47.3	Years	77.2	Years

[a]TOE: Ton oil equivalent; MTOE: million ton of oil equivalent; MMTCE: million metric ton of carbon equivalent; MTCE: metric ton of carbon equivalent; ppmv: part per million by volume; [b] including hydroelectric power, biomass, geothermal, solar and wind energy.

The total amount of carbon on earth is constant and its distribution among lithosphere, atmosphere and biosphere was relatively balanced until the advent of era of industrialized civilization. The CO_2 concentration in the atmosphere is increasing. Figure 1.1 shows the change of atmospheric CO_2 level over the years between 1000 and 1997 and actual CO_2 level during 1958–2004 (Song C, 2006). CO_2 level increased from 280 ppmv in 1000 to 295 ppmv in 1900 based on Antarctica ice core data. It increased to 315 ppmv in 1958 and further to 377 ppmv in 2004 based on actual data logged in Hawaii.

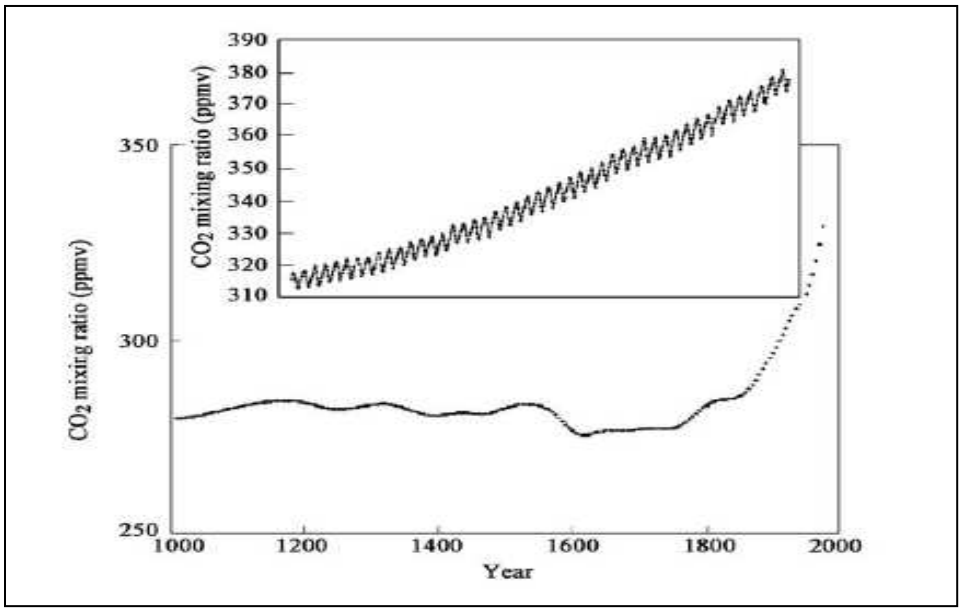

Figure 1.1: Atmospheric CO_2 concentrations during 1000–2004 based on the analysis of ice cores and logged atmospheric CO_2 concentrations during 1958–2004 (Song C, 2006).

Capture of CO_2 contributes 75 percent to the overall CCS cost and CCS increases the electricity production cost by 50 percent (Feron and Hendriks, 2005). Although these numbers may vary with different CCS schemes, cutting the capture cost is the most important issue for the CCS process to be acceptable to the energy industry. Hence, this study mainly focuses on the progress in technologies of CO_2 separation from the chemical conversion point of view. There are many options for CO_2 separation and these include adsorption, absorption, membrane and biotechnology.

1.2 Adsorption

Adsorption is defined as the formation of a layer of gas, liquid, or solid on the surface of a solid or, less frequently of a liquid. There are two types depending on the nature of the forces involved. In chemistry a single layer of molecules, atoms, or ions is attached to the adsorbent surface by chemical bonds. When an adsorbent attracts molecules from the gas, the molecules become concentrated on the surface of

the adsorbent and are removed from the gas phase. In physisorption adsorbed molecules are held by the weaker van der Waals' forces. (Oxford Dictionary of Chemistry, 2000). Adsorptions involve the binding of molecules from their liquid or gaseous environment onto the surface of solids. It is a separation process for the selective removal small quantities of components from a fluid mixture or solution. (Ralph T. Yang, 1997). Adsorption is the process of transferring material from a fluid phase to a solid phase. (W. John Thomas, 1998).

1.3 Absorption

Gas absorption is a process in which soluble components of gas mixture are dissolved in a liquid phase. The gas and liquid normally flow counter currently among some packing which serve to provide the contacting of interfacial surface through which mass transfer take place. (Sunggyu Lee, 2006). Absorption is the take up of a gas by liquid, or the take up of a liquid by a solid. Absorption differs from adsorption in that the absorbed substance permeates the bulk of the absorbing substance; (taken up by volume not by surface). Overall, gas absorption maybe described as the partition of gas between gas and liquid phases. This partition or absorption of a gas is generally discussed in terms of the equilibrium between soluble gas in the gas phase and dissolved gas in the liquid phase. (Oxford Dictionary of Chemistry, 2000). Absorption of gases in the liquid phase is a process of simultaneous mass and heat transfer. (Roman Zarzycki, 1993).

1.4 Problem Statement

The growth in scale of gas-phase adsorption separation processes, particularly since 1970 is due to continuing discoveries of new, porous, high surface-area adsorbent materials (particularly molecular sieve zeolites) and especially to improvements in the design and modification of adsorbents. These advances have encouraged parallel inventions of new process concepts.

Chemical absorption of CO_2 in a packed column will be very effective using various adsorbent. (D.Georgiou, 1999). Many research have been conducted in recent years on the subject of gas adsorption using a single adsorbent such as activated carbon, zeolite, silica gel, activated alumina and lime soda. But in this study, the removal performance of CO_2 gas is compare by using two adsorbent; granular activated carbon and silver exchanged zeolite.

1.5 Objectives

The objectives of this study will focus on:

i. To compare the effect of changing the gas removal techniques using various gas flow rate (100, 75 and 50 m^3/hr) and water flow rate (250 and 200 L/hr) at constant pressure 1 bar with temperature 37°C.
ii. To study the performance on the CO_2 gas removal from different adsorbent; with the present and absent of zeolites.

1.6 Scope of Study

In this study, the removal performances of CO_2 gas will concentrate on adsorption and absorption techniques using Gas Adsorption-Absorption Unit model CE130. The experiment had been run at the constant pressure and temperature (1 bar and 37°C). The performance is analyzed by comparing the liquid flow rate at 250 and 200 L/hr with gas flow rate 100, 75 and 50 m^3/hr and composition of CO_2 dissolved in water. The experiment had been run twice at different condition; with the present and absent of zeolites.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Over the past century, the Earth has increased in temperature by about 5 °C and many scientists believe this is because of an increase in concentration of the main greenhouse gases; carbon dioxide, methane, nitrous oxide, and fluorocarbons. The green house effect is the heating of the Earth due to the presence of greenhouse gases. It is named this way because of a similar effect produced by the glass panes of a greenhouse. Shorter-wavelength solar radiation from the sun passes through Earth's atmosphere and then is absorbed by the surface of the Earth causing it to warm as in Figure 2.1.

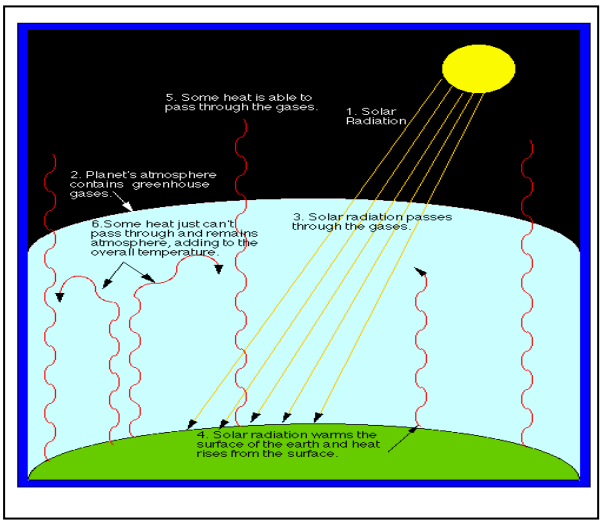

Figure 2.1: The process of global warming and how greenhouse gases create the greenhouse effect. (M.A.L.Caetano, 2008)

Carbon dioxide (CO_2) is a colorless, odorless non-flammable gas and is the most prominent Greenhouse gas in Earth's atmosphere as shown in Figure 2.2. It is recycled through the atmosphere by the process photosynthesis which makes human life possible.

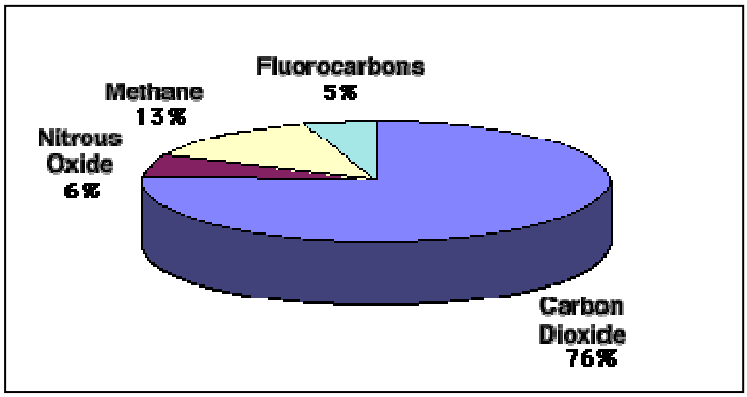

Figure 2.2: The distribution of GHG in Earth's atmosphere. (Nordhaus, 1991)

Deforestation is the main producer of carbon dioxide. The causes of deforestation are logging for lumber, pulpwood, and fuel wood. Also contributing to deforestation is clearing new land for farming and pastures used for animals. Fossil Fuels were created chiefly by the decay of plants from millions of years ago. They use coal, oil and natural gas to generate electricity, heat the homes, power the factories and run the cars. These fossil fuels contain carbon. When they are burned, they combine with oxygen to form carbon dioxide. (Nordhaus, 1991)

The World Energy Council reported that global carbon dioxide emissions from burning fossil fuels rose 12% between 1990 and 1995 (UNEP, 2007). The increase from developing countries was three times that from developed countries. Middle East carbon dioxide emissions from burning of fossil fuels increased 35%, Africa increased 12%, and Eastern Europe increased rates by 75% from 1990-1995. Figure 2.3 shows the increase of carbon dioxide in the air over the past few centuries.

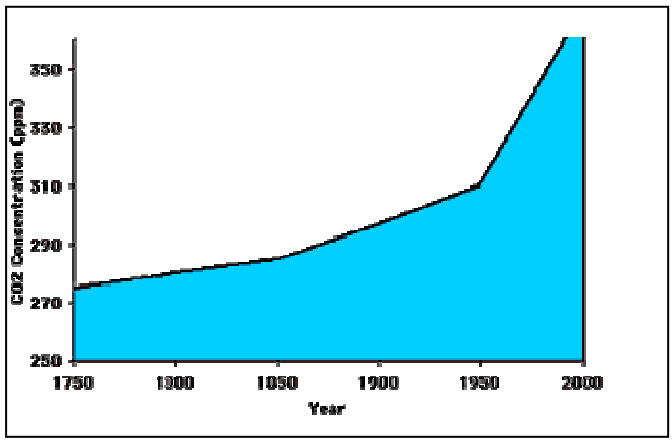

Figure 2.3: The increase of carbon dioxide in the air (UNEP, 2007)

2.2 Fundamentals

2.2.1 Adsorption Principles

The potential theory of adsorption was first introduced by Polanyi (1914) and later modified by Dubinin (1915) for adsorption on micro porous adsorbents. The theories are still regarded as fundamentally sound and accepted as correct as and better than all the other theories. This longevity of the theory is due to its essentially thermodynamic character and lack of insistence on a detailed physical picture.

It is based on the idea that at the surface of the solid adsorbent, the adsorbed molecules of the gas or vapor are compressed by the forces of attraction acting from the surface to a distance into the surrounding space. Because the forces anchoring a molecule to the surface decay with distance, a multi molecular adsorbed film may be regarded as lying in an intermolecular potential gradient. The force of attraction at any given point in the adsorbed film can be conveniently measured by the adsorption potential, ε which is defined as the work done by the adsorption forces in bringing a molecule from the gas phase to that point. (Polanyi, 1914) concept of the cross-section for a typical gas-solid system can be represented as shown in Figure 2.4.